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Examining Wind Stress and Wind Waves in the Presence of Swell

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Abstract— **A case study of the air-sea drag coefficient as measured off the coast of North Carolina using a low-flying aircraft suggests that the presence of following wind swell was associated with low drag values. Shorter wave slope variance at the m and cm-scale was also depressed for these moderate wind cases. The results here are not conclusive but are consistent with recent results showing some impact of the swell and that following-wind swell is associated with the lowest drag coefficient levels.**

I. Introduction

The questions of how wind and ocean waves interact and how this coupling should be parameterized to optimally derive the surface wind stress remain open and central to estimating air-sea coupling at the global and local scales. While much attention has been given to evaluating the effect of the wind-driven waves upon the surface wind stress and air-sea drag coefficient, less emphasis has been given to the more common and more complex mixed sea case. At any given instant, much of the global ocean's wave energy is carried in its swell fields. In fact, the majority of long wave spectra over the seas will exhibit a mixture of locally coupled wind waves and swell that is aligned in some arbitrary fashion with respect to the local wind direction. Recent work [1-5] suggests that the swell can and does act to alter the sea drag at light-to-moderate wind conditions. The swell phase speed and direction with respect to the wind vector, the steepness of the swell, and the relative energy of the swell versus the sea are all discussed as factors in this influence. Theoretical work [4] suggests that swell exchanges energy through two mechanisms: the correlation of pressure and wave slope (form drag), and the work of surface turbulent stress against the swell orbital velocity. Observation and theory suggest that it is the case of wind-opposed swell that provides the most substantial increase in the 10 m drag coefficient. An additional point of consideration is the possibility that the wave-induced momentum flux can systematically alter the assumed logarithmic form for the wind profile, perhaps calling into question the use or derivation of a 10 m drag coefficient in some cases.

A goal of the present paper is to provide some additional observations for consideration. In particular, the focus will be upon cases where there is a severe drop in the drag coefficient that occurs in conditions of stable boundary conditions and relatively strong swell fields. Data come from Office of Naval Research's Shoaling Waves Experiment (SHOWEX). The primary measurements to be discussed were obtained using a low-flying aircraft that collected both atmospheric and wave field measurements. Another point of interest is to see when observed variability in the drag and short wave statistics covary. This emphasis is driven by the need to use short-wave remote sensing techniques to derive the wind stress information from satellites.

IV. Summary

Field observations are presented that provide some further support for the effects of swell on the 10 m air-sea drag coefficient. The investigation here is preliminary and focused on cases where the drag coefficient dropped to very low levels at moderate wind speeds. Preliminary results indicate the drag depression is occurring when the swell travels nearly in a following-wind direction. The short wave steepness in both the intermediate and cm-scale was reduced for these cases but not with the magnitude seen in the drag.

Some common obstacles to further clarification are being addressed. These include self-correlation, isolation of atmospheric stability effects, and perhaps most importantly understanding the influence of the vertical profile on the observed drag and on the inferences that can be drawn using the single level aircraft data for the limited cases presented. The recent studies cited (e.g. [1, 4] indicate that the inner (wave) and outer boundary layer structure may be quite different for the case of swell dominance as opposed to well-couple wind waves. Further examination of the aircraft wind and wave cospectra should aid in this effort.